

AL11 - Relocation of a 400 kA Potline – Pot Upgrade and Energy Saving Roadmap

Zhuojun Xie¹, Weibo Li², Jian Lu³, Zheng Liu⁴ and Hailong Guo⁵

1. Process Engineer

3. Chief Engineer

4. General Director

5. Chief Engineer

Guiyang Aluminum & Magnesium Design & Research Institute, Co., Ltd. Guiyang, China

2. General Manager

Guangyuan Zhongfu High Precision Aluminum Co., Ltd. Guangyuan, China

Corresponding author: zhj_xie@chalieco.com.cn

Abstract

In 2018, a Chinese 400 kA potline was shut down due to high energy consumption and lack of competitiveness. The potline was originally designed in 2006 as the first-generation 400 kA reduction cells by a Chinese aluminum reduction technology provider. In order to survive in the fierce competition, the smelter decided to relocate from Henan Province to Sichuan Province, a place that has abundant hydroelectric power resources and a larger environmental capacity. Guiyang Aluminum & Magnesium Design and Research Institute Co., Ltd. (GAMI) was selected as technology provider for this relocation project. In order to achieve lower power consumption targets, pot upgrading and modifications to the auxiliary systems were decided for this project. After upgrading, the potline was successfully restarted in November 2019, and its specific energy consumption was 500 kWh/t Al lower than before. This article shares the energy saving roadmap of this relocation project.

Keywords: Aluminum reduction potline relocation, Pot technology upgrading, Energy saving.

1. General Description

This project constitutes a relocation initiative involving the transfer of operations from Henan to Sichuan. Its original configuration contains a single potline, equipped with a total of 234 cells. The potline was originally designed in 2006 as the first-generation 400 kA reduction cells by a Chinese aluminum reduction technology provider. To mitigate financial outlay, the underlying design philosophy prioritizes the relocation of existing large-scale equipment from each workshop, obviating the need for new purchases. Consequently, the core equipment remains unaltered, while selective optimization and transformation are implemented on specific components, thus fostering advantageous circumstances conducive to achieving improved technical and economic performance indicators. Figure 1 shows the relocation project timeline.

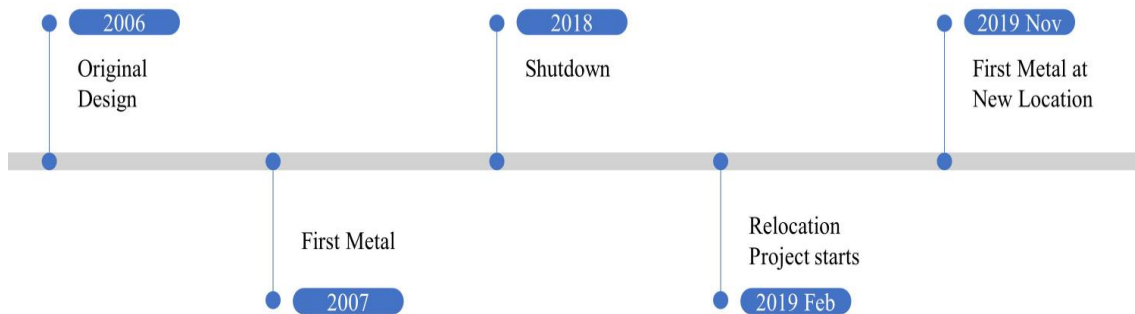


Figure 1 Relocation project timeline.

2. Busbar System

As known, the main driving force for the molten metal and bath inside the cell is the electromagnetic force:

$$\mathbf{F} = \mathbf{J} \times \mathbf{B} \quad (1)$$

where:

- F** Electromagnetic force vector, N/m³,
- J** Electric current density vector, A/m²,
- B** Magnetic induction (flux density), T (or G), 1 mT = 10 G,
- X** Vector cross product

Therefore, the horizontal current in the metal layer and vertical magnetic field create the wave-driving force, which is mainly generated by the magnetic field of the busbar system. Due to the limited investment of the owner in this project, the owner's requirement for the busbar system of this project was to maximize the utilization of the old busbars. Therefore, GAMI's approach was to first calculate the magnetic field of the existing busbar system.

Calculation results of original design show that the magnetic field is high. Maximum vertical magnetic field $|B_z|$ is 2.78 mT (27.8 G), while the average value of $|B_z|$ is 0.62 mT (6.2 G). The area with $|B_z| < 1$ mT (10 G) accounts for 83.3 %. Values and distribution of vertical magnetic field are indicated in Table 1 and Figure 2.

Table 1. Magnetic field distribution in four quadrants before busbar modification (G).

	1 st quadrant	2 nd quadrant	3 rd quadrant	4 th quadrant
$ B_z $	6.15	6.36	6.41	5.89

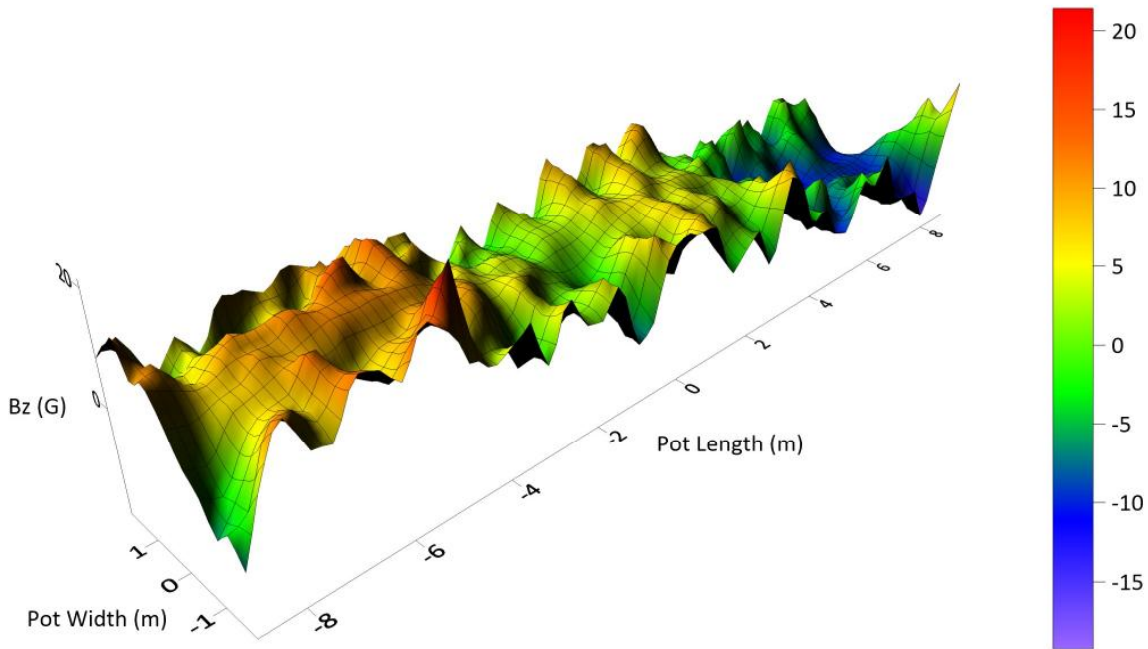


Figure 2 B_z Distribution before busbar modification (G).

Starting from the research by Sele [1], magnetic field judgement criteria was described. However, those criteria cannot meet the requirements for today's MHD stability. According to the evaluation criteria established by GAMI during the development of large-scale cells, in order to obtain good MHD stability, the vertical magnetic field must meet the following criteria [2]:

- The maximum absolute value is within 2 mT (20 G).
- The average of absolute values is within 0.5 mT (5 G).
- The area with $|B_z| < 1$ mT (10 G) shall be greater than 80 %.

The calculation results of the magnetic field of the existing busbar system obviously do not meet the above criteria, but the gradient of the magnetic field is acceptable. According to the owner's request, in order to save the owner's investment as much as possible, GAMI only optimized part of the busbar without making major changes. Modification details of busbar system is indicated in Table 2.

Table 2. Modification details of busbar system.

Part of busbar system	Modification or not
Busbar around pot	Minor modification
Anode beam busbar	No modification
Riser busbar	No modification

After optimization, maximum vertical magnetic field $|B_z|$ is 2.52 mT (25.2 G), while the average value of $|B_z|$ is 0.53 mT (5.3 G). The area with $|B_z| < 1$ mT (10 G) accounts for 89.3 %. Values and distribution of vertical magnetic field are indicated in Table 3 and Figure 3.

Table 3. Magnetic field distribution in four quadrants after busbar modification (G).

	1 st quadrant	2 nd quadrant	3 rd quadrant	4 th quadrant
$ B_z $	5.20	5.42	5.33	5.21

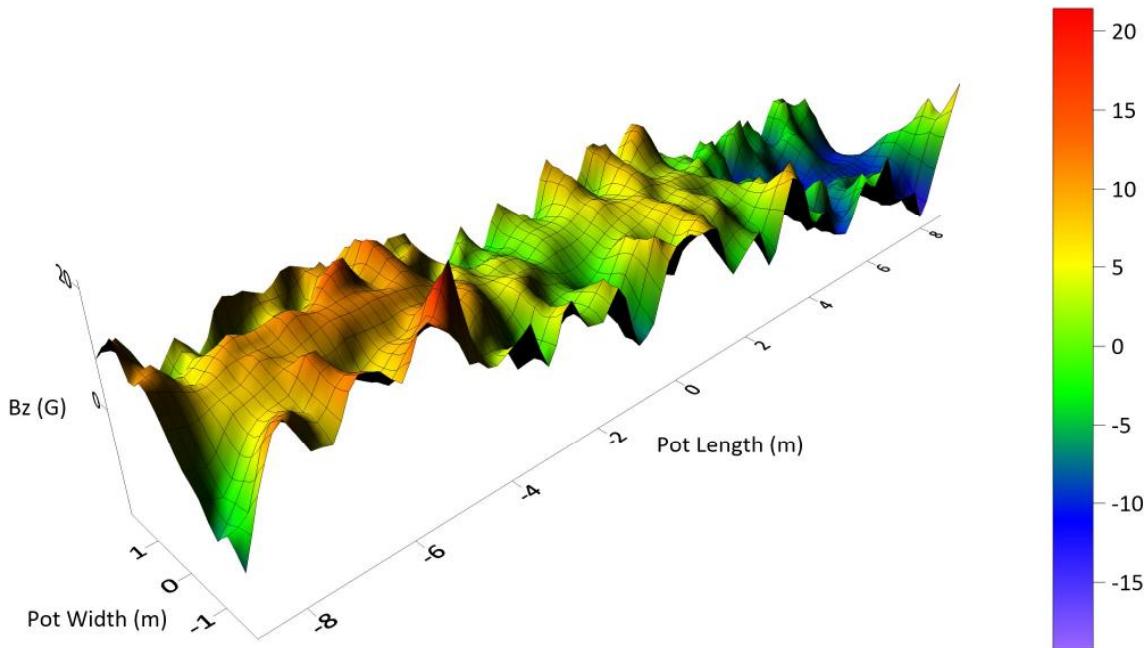


Figure 3. B_z Distribution after busbar modification (G).

Although the improved result did not meet GAMI's evaluation criteria for "good magnetic field", it has been improved compared with the original busbar system. After the improvement, the magnetic field distribution in the four quadrants is more uniform, and the maximum value of $|B_z|$ is reduced. The area with $|B_z| < 1$ mT (10 G) increased by 6.0 %. After the optimization of the busbar system, the magnetic field distribution is more reasonable, and B_z distribution has a much more important role on MHD stability than absolute maximum B_z value [3].

3. Energy Saving Lining Design

Since this project is a relocation project, all cell linings have been removed before relocation. Therefore, the lining design was determined to be new from the very beginning of this project. The design of the lining of the cell is critically related to the economic indicators of the cell production and the life of the cell and is the core technology of the cell design. This project adopts the new energy-saving lining design technology developed and successfully promoted by GAMI. This technology takes energy saving as the ultimate goal. Through the international advanced simulation computing platform, the static balance of the cell is overall optimized, the ledge profile and isotherm lines are reasonably distributed, and the stable, high-efficiency and low-consumption production can be realized.

In this project, we use the following boundary conditions for lining simulation calculations, listed in Table 4:

Table 4. Boundary conditions for lining calculation.

Item	Unit	Value
Potline current	kA	400
Bath temperature	°C	950
Liquidus temperature	°C	942
Ambient temperature	°C	35
Metal level	cm	25
Bath level	cm	18
Anode covering height	cm	20
Cathode type	/	30 % graphitic

The calculation results are shown in Figures 4 and 5.

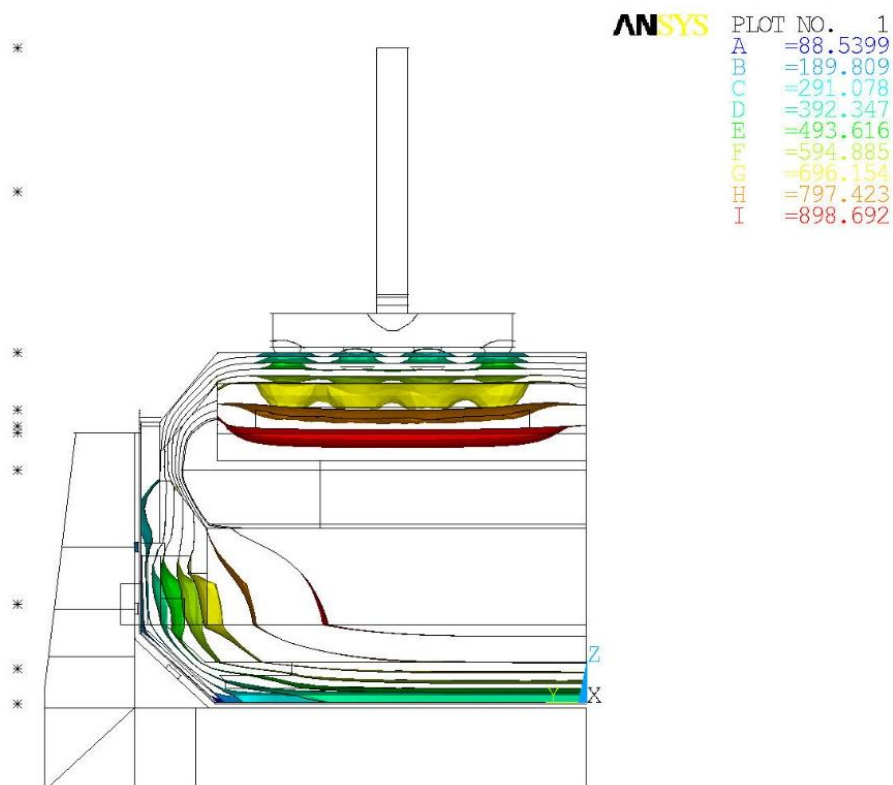


Figure 4. Cross-section temperature distribution contour map.

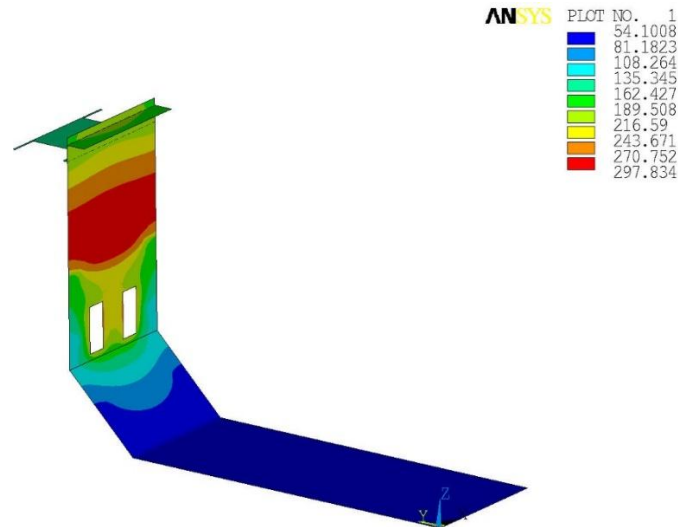


Figure 5. Temperature distribution contour map of potshell.

Another criterion for the design of the lining structure of the modern aluminum reduction cell is to position the 900 °C isotherm (acid electrolyte eutectic isotherm) below the cathode carbon block and above the lining insulation layer, so as to avoid the impact of high temperature compounds such as sodium infiltration. As can be seen from Figure 4, the lining structure of this design can obtain such effect.

4. Gas Collection System

In the original design, the gas collection system of the cell was a "V"-shaped flue design. We made a simulation to show the gas collection efficiency of the duct, and the negative pressure at the outlet of the flue pipe was -200 Pa. The velocity vectors in the duct are indicated in Figure 6, and air flow rate is listed in Table 5. It can be seen from the figure and the table that the distribution of the gas collection volume of the entire duct is uneven, resulting in poor gas collection. And the total flow is 18 286 m³/h, which exceeds the typical value of a 400 kA cell.

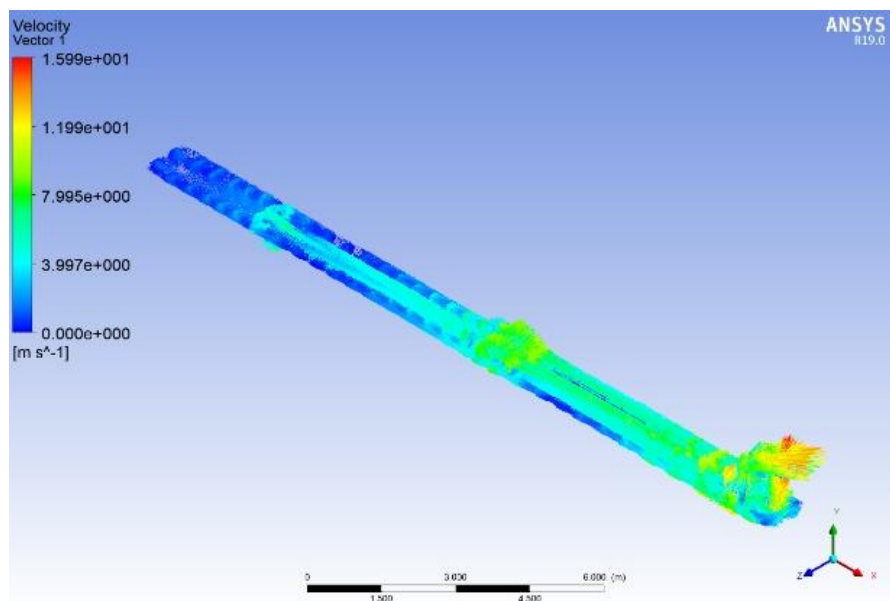


Figure 6. Velocity vectors in the gas collection duct in the original design.

Table 5. Gas flow rate in the duct of the original design.

Segment	Volume flow (m ³ /h)	Average flow/segment (m ³ /h)	Deviation from average (%)
1	3004	3048	1.4
2	2450		19.6
3	2255		26
4	4637		52.2
5	3295		8.1
6	2645		13.2
TOTAL	18286		

Therefore, in this project, we changed the structure of the gas collection duct to the "lift-up" design, which greatly improved the gas collection efficiency. At the same time, the gas collection volume of the entire duct is evenly distributed, the relative deviation between each section is small. And the total flow has also dropped to 15 655 m³/h, which is a typical value for a 400 kA cell. The velocity vectors in the new duct are indicated in Figure 7, and the gas flowrate is listed in Table 6.

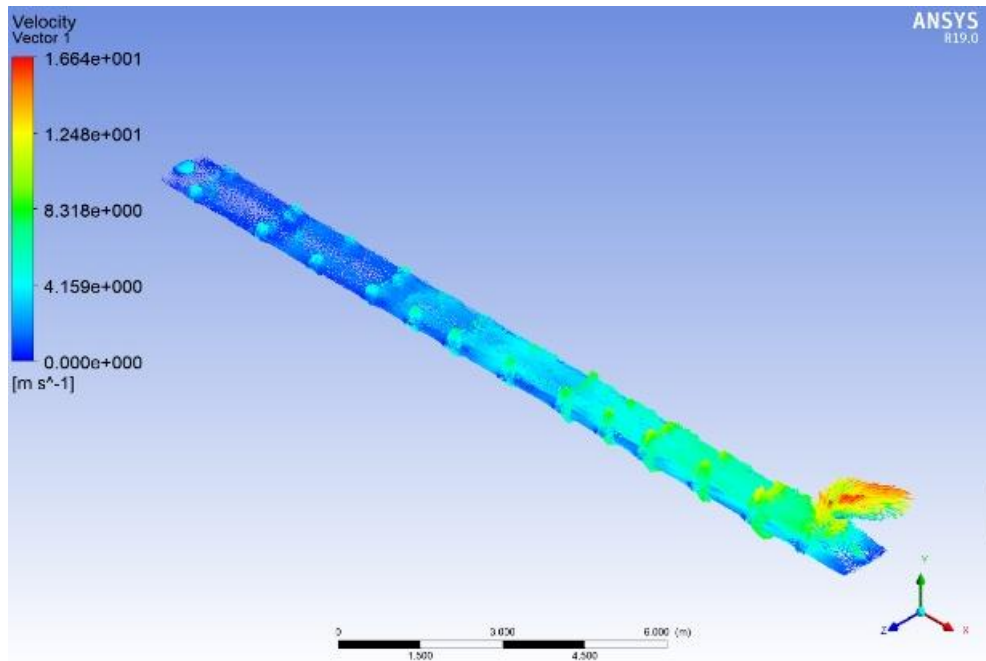


Figure 7. Velocity vectors in the gas collection duct of the retrofitted design.

Table 6. Gas flow rate in the duct of the retrofitted design.

Segment	Volume flow (m ³ /h)	Average flow (m ³ /h)	Deviation (%)
1	2665	2609	2.1
2	2630		0.8
3	2539		-2.7
4	2622		0.5
5	2603		-0.2
6	2594		-0.6
TOTAL	15 655		

5. Potroom Ventilation

Due to the relocation of this project from the northern region of China to the southern region of China, the climate is hotter. Therefore, in this project, the ventilation structure of the potrooms was redesigned. The temperature distribution in the potroom building at 1.5 m above the potroom operation floor is shown in Figure 8.

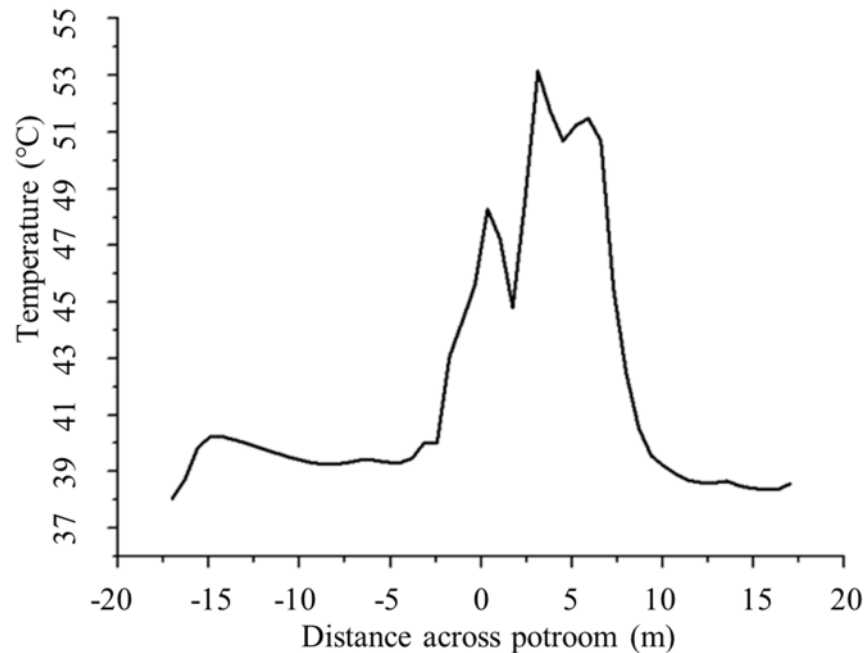


Figure 8. The temperature distribution at 1.5 m above the potroom operation floor (Left: tap end; Right: duct end, ambient temperature: 35 °C).

It can be seen that this kind of potroom ventilation can successfully control the temperature of the operating surface of the tap end below 40 °C in summer, and thereby can alleviate the heatstroke of workers in summer.

6. Other Measures to Decrease Energy Consumption

Apart from the above-mentioned major modifications, there are some small modifications that also help to decrease the energy consumption.

For example, this project features high-conductivity and energy-saving anode stub technology. This technology uses a brand-new material and sprays an anti-oxidation coating on the surface of the anode and the steel stubs. This can effectively reduce the voltage drop of the steel stubs by 15 mV, which is equivalent to saving 48 kWh/t Al electricity. In addition, due to serious damage to the hoods of some cells, this project replaced the damaged hoods with new thermal insulation hoods, and these hoods were used for the whole pot (that is, old hoods and new hoods are not mixed on one single cell). The cell using the new hoods can effectively reduce the heat loss by 25 mV, which is equivalent to saving 80 kWh/t Al of electrical energy. These measures have obvious effects on improving the energy consumption of the cell.

7. New Concept of Alumina Transportation System

In fact, before this project, the starting point of the alumina conveying system in Chinese aluminum smelters was generally set outside the potroom. In order to save transmission power consumption, this project creatively designed the starting point of the alumina transmission system in the courtyard area. Thanks to the good raw material availability in the Guangyuan region, the storage space does not need to be large (this project has the alumina storage capacity of 10 days), which allows the alumina warehouse to be put inside the crowded courtyard area. Figure 9 shows such a creative design.



Figure 9. The starting point of conveying system (traditional vs this project).

In addition, the alumina conveying system of this project uses bucket elevators and hyper-dense phase-system (HDPS) instead of dense phase system (DPS). This is done in order to further reduce power consumption, because the mechanical conveying method will save electricity compared with the pneumatic conveying system. With this design, the power consumption of alumina transportation system is 40 kWh/t Al lower than before the relocation.

8. Summary and Industrial Performance

The main retrofit changes of this project are shown in Table 7. We estimated the power consumption that can be saved by each retrofit part compared with the original design:

The operating key performance indicators (KPIs) for one year before the potline shutdown was 13 173 kWh/t Al (DC power consumption) and 92.3 % current efficiency. After the retrofit, the KPIs became 12 700 kWh/t Al (DC power consumption), 93.2 % current efficiency. The DC power consumption reduced by 473 kWh/t Al. And in terms of the AC power consumption, more than 500 kWh/t Al has been saved.

Table 7. Project retrofit changes and benefits.

Item	Original	Retrofitted	Benefit kWh/t Al
Busbar system	6 risers, asymmetrical design	Minor modification	30
Lining design	Traditional design	Energy saving lining design	300
Gas collection system	V shape flue	Lift up flue	30
Potroom ventilation	Northern China Typical Design	GAMI Southern China Proprietary Design	/
Anode stub	Traditional design	New material and coating	48
Hood	Traditional design	Partial modification	80
Alumina conveying system	Long distance, DPS + HDPS	Short distance, Bucket elevators + HDPS	40
Shell	Traditional design	Unchanged	/
Superstructure beam	Truss structure design	Unchanged	/
TOTAL			528

Table 8. Key performance indicators for 400 kA potline.

Item	Unit	Original	Retrofitted			
			2020	2021	2022	Average
Current	kA	400.1	400.2	400.1	395.4	398.6
CE (tapping)	%	92.3	93.3	93.2	93.2	93.2
DC Power Consumption	kWh/t Al	13 173	12 648	12 694	12 758	12 700

Note: Only the period of normal operation is calculated.

The power consumption in 2022 is higher than that in 2021 and 2020. This is because in 2022 Sichuan Province has less rainfall and hot weather, resulting in tight power supply. The potline was requested to shut down in August. The restart has taken place in September. This has caused a certain degree of shock to KPIs.

The on-site photos of the aluminum plant after transformation are shown in Figure 10. The factory is very clean, which also proves that the modification of the gas collection system is successful.



Figure 10. Retrofitted potroom (photo taken in May 2023).

9. Conclusion

This project successfully relocated an old 400 kA aluminum electrolysis potline, and after a series of upgrades, it reduced its operating power consumption by more than 500 kWh/t Al. In addition to upgrading and transforming the traditional cell to save energy, this project also saves a lot of power consumption in the auxiliary system, which shows that the new concept of public and auxiliary system design can bring huge economic benefits to the aluminum plant. The possibility of reducing the power consumption by modifying the auxiliary system is usually ignored by smelters, and this project sets a very good example for the future of old smelters.

10. References

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